# Types, Operators and Expressions

EECS 2031



## Variable Names (2.1)

- Combinations of letters, numbers, and underscore character ( _ ) that
  - do not start with a number;
  - are not a keyword.
- Upper and lower case letters are distinct (x ≠ X).
- Examples: Identify valid and invalid variable names

```
abc, aBc, abc5,  aA3_ , char, _360degrees,
5sda, my_index, _temp, string, struct,
pointer
```

## Variable Names: Recommendations

- Don't begin variable names with underscore _
- Limit the length of a variable name to 31 characters or less.
- Function names, external variables: may be less than 31 characters allowed, depending on systems.
- Lower case for variable names.
- Upper case for symbolic constants
  - `#define MAX_SIZE 100`
- Use short names for local variables and long names for external variables.

3

## Data Types and Sizes (2.2)

4 basic types in C

- **char** – characters (8 bits)
- **int** — integers (either 16 or 32 bits)
- **float** – single precision floating point numbers (4 bytes)
- **double** – double precision floating point numbers (8 bytes)

4

## Qualifiers: short and long

- Applied to int and double

- short int s; /* 16 bits, -32,768 - +32,767 */
  - short s;
- long int counter; /* 32 bits */
  - long counter;
  - int is either 16 or 32 bits, depending on systems.

- long double ld; /* 12 or 16 bytes */
- No "short double", which is float

5

## Qualifiers: unsigned and signed

- Applied to int and char

- signed char sc; /* -127 – +128 */
- unsigned char uc; /* 0 – +255 */
- Is char signed or unsigned?
- Printable characters are always positive.

- unsigned int uint;
  - 0 – +4,294,967,295, assuming 4-byte int
- signed int sint; /* same as int sint; */

6

## Qualifiers

- <limits.h> and <float.h> contain
  - symbolic constants for all of the above sizes,
  - other properties of the machine and compiler.

- To get the size of a type, use **`sizeof`**( )

```
int_size = sizeof( int );
```

Examples: http://www.lix.polytechnique.fr/~liberti/public/computing/prog/c/C/SYNTAX/sizeof.html

7

## Data Types: Homework

- Write a program to determine the ranges of **`char`**, **`short`**, **`int`** and **`long`** variables, both signed and unsigned, by printing appropriate values from standard headers (file <limits.h> and by direct computation).
- Write a program to determine the ranges of **`float`**, **`double`** and **`long double`** variables by printing appropriate values from standard headers (file <float.h>).

  *Note*: see Appendix B.11 for the above problems
- Write a program to determine the sizes of **`char`**, **`short`**, **`int`**, **`long`**, **`float`**, **`double`** and **`long double`** variables using the **`sizeof`** operator.

8

# Characters

- 8 bits
- Included between 2 single quotes

  **`char x = 'A'`**
- Strings: enclosed between 2 double quotes

  **"`This is a string`"**
- Note: 'A' ≠ "A"

| A | A | \0 |
|---|---|---|

- **`c = '\012'`** /* 10 decimal; new line character */



# Characters

| Dec | Hx | Oct | Char | Dec | Hx | Oct | Html | Chr | Dec | Hx | Oct | Html | Chr | Dec | Hx | Oct | Html | Chr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 000 | NUL (null) | 32 | 20 | 040 |   | Space | 64 | 40 | 100 | @ | @ | 96 | 60 | 140 | ` | ` |
| 1 | 1 | 001 | SOH (start of heading) | 33 | 21 | 041 | ! | ! | 65 | 41 | 101 | A | A | 97 | 61 | 141 | a | a |
| 2 | 2 | 002 | STX (start of text) | 34 | 22 | 042 | " | " | 66 | 42 | 102 | B | B | 98 | 62 | 142 | b | b |
| 3 | 3 | 003 | ETX (end of text) | 35 | 23 | 043 | # | # | 67 | 43 | 103 | C | C | 99 | 63 | 143 | c | c |
| 4 | 4 | 004 | EOT (end of transmission) | 36 | 24 | 044 | $ | $ | 68 | 44 | 104 | D | D | 100 | 64 | 144 | d | d |
| 5 | 5 | 005 | ENQ (enquiry) | 37 | 25 | 045 | % | % | 69 | 45 | 105 | E | E | 101 | 65 | 145 | e | e |
| 6 | 6 | 006 | ACK (acknowledge) | 38 | 26 | 046 | & | & | 70 | 46 | 106 | F | F | 102 | 66 | 146 | f | f |
| 7 | 7 | 007 | BEL (bell) | 39 | 27 | 047 | ' | ' | 71 | 47 | 107 | G | G | 103 | 67 | 147 | g | g |
| 8 | 8 | 010 | BS (backspace) | 40 | 28 | 050 | ( | ( | 72 | 48 | 110 | H | H | 104 | 68 | 150 | h | h |
| 9 | 9 | 011 | TAB (horizontal tab) | 41 | 29 | 051 | ) | ) | 73 | 49 | 111 | I | I | 105 | 69 | 151 | i | i |
| 10 | A | 012 | LF (NL line feed, new line) | 42 | 2A | 052 | * | * | 74 | 4A | 112 | J | J | 106 | 6A | 152 | j | j |
| 11 | B | 013 | VT (vertical tab) | 43 | 2B | 053 | + | + | 75 | 4B | 113 | K | K | 107 | 6B | 153 | k | k |
| 12 | C | 014 | FF (NP form feed, new page) | 44 | 2C | 054 | , | , | 76 | 4C | 114 | L | L | 108 | 6C | 154 | l | l |
| 13 | D | 015 | CR (carriage return) | 45 | 2D | 055 | - | - | 77 | 4D | 115 | M | M | 109 | 6D | 155 | m | m |
| 14 | E | 016 | SO (shift out) | 46 | 2E | 056 | . | . | 78 | 4E | 116 | N | N | 110 | 6E | 156 | n | n |
| 15 | F | 017 | SI (shift in) | 47 | 2F | 057 | / | / | 79 | 4F | 117 | O | O | 111 | 6F | 157 | o | o |
| 16 | 10 | 020 | DLE (data link escape) | 48 | 30 | 060 | 0 | 0 | 80 | 50 | 120 | P | P | 112 | 70 | 160 | p | p |
| 17 | 11 | 021 | DC1 (device control 1) | 49 | 31 | 061 | 1 | 1 | 81 | 51 | 121 | Q | Q | 113 | 71 | 161 | q | q |
| 18 | 12 | 022 | DC2 (device control 2) | 50 | 32 | 062 | 2 | 2 | 82 | 52 | 122 | R | R | 114 | 72 | 162 | r | r |
| 19 | 13 | 023 | DC3 (device control 3) | 51 | 33 | 063 | 3 | 3 | 83 | 53 | 123 | S | S | 115 | 73 | 163 | s | s |
| 20 | 14 | 024 | DC4 (device control 4) | 52 | 34 | 064 | 4 | 4 | 84 | 54 | 124 | T | T | 116 | 74 | 164 | t | t |
| 21 | 15 | 025 | NAK (negative acknowledge) | 53 | 35 | 065 | 5 | 5 | 85 | 55 | 125 | U | U | 117 | 75 | 165 | u | u |
| 22 | 16 | 026 | SYN (synchronous idle) | 54 | 36 | 066 | 6 | 6 | 86 | 56 | 126 | V | V | 118 | 76 | 166 | v | v |
| 23 | 17 | 027 | ETB (end of trans. block) | 55 | 37 | 067 | 7 | 7 | 87 | 57 | 127 | W | W | 119 | 77 | 167 | w | w |
| 24 | 18 | 030 | CAN (cancel) | 56 | 38 | 070 | 8 | 8 | 88 | 58 | 130 | X | X | 120 | 78 | 170 | x | x |
| 25 | 19 | 031 | EM (end of medium) | 57 | 39 | 071 | 9 | 9 | 89 | 59 | 131 | Y | Y | 121 | 79 | 171 | y | y |
| 26 | 1A | 032 | SUB (substitute) | 58 | 3A | 072 | : | : | 90 | 5A | 132 | Z | Z | 122 | 7A | 172 | z | z |
| 27 | 1B | 033 | ESC (escape) | 59 | 3B | 073 | ; | ; | 91 | 5B | 133 | [ | [ | 123 | 7B | 173 | { | { |
| 28 | 1C | 034 | FS (file separator) | 60 | 3C | 074 | < | < | 92 | 5C | 134 | \ | \ | 124 | 7C | 174 | | | \| |
| 29 | 1D | 035 | GS (group separator) | 61 | 3D | 075 | = | = | 93 | 5D | 135 | ] | ] | 125 | 7D | 175 | } | } |
| 30 | 1E | 036 | RS (record separator) | 62 | 3E | 076 | > | > | 94 | 5E | 136 | ^ | ^ | 126 | 7E | 176 | ~ | ~ |
| 31 | 1F | 037 | US (unit separator) | 63 | 3F | 077 | ? | ? | 95 | 5F | 137 | _ | _ | 127 | 7F | 177 | &#127; | DEL |

Source: www.LookupTables.com

## Constants (2.3)

- Numeric constants
- Character constants
- String constants
- Constant expressions
- Enumeration constants

11

## Integer Constants

- Decimal numbers
  - `123487`
- Octal: starts with 0 (zero)
  - `0654`
- Hexadecimal: starts with 0x or 0X
  - `0x4Ab2, 0X1234`
- long int: suffixed by L or l
  - `7L, 106l`
- unsigned int: suffixed by U or u
  - `8U, 127u`

12

## Floating-point Constants

- Contain a decimal point, an exponent, or both.

```
15.75
1.575E1   /* = 15.75 */
1575e-2   /* = 15.75 */
-2.5e-3     /* = -0.0025 */
25E-4              /* = 0.0025 */
100.0
```

- You may omit the integer portion if it is zero.

```
.0075e2
.075e1
75e-2
```

13

## Floating-point Constants (cont.)

- If there is no suffix, the type is considered **double** (8 bytes).
- To specify **float** (4 bytes), use suffix **F** or **f**.
- To specify **long double** (12 or 16 bytes), use suffix **L** or **l**.

```
100.0L  /* long double */
100.0F  /* float */
100.0    /* double */
```

14

## Numeric Constants

| | |
|---|---|
| `2010` | int |
| `100000` | taken as long if 16-bit int |
| `729L or 729l` | long (int) |
| `2010U or 2010u` | unsigned |
| `20628UL or 20628ul` | unsigned long |
| `24.7 or 1e-2` | double |
| `24.7F or 24.7f` | float |
| `24.7L or 24.7l` | long double |
| `037` | octal (= 31 decimal) |
| `0x1f, 0X1f, 0x1F` | hexadecimal (= 31) |
| `0XFUL` | What is this? |

15

## Character Constants

| | |
|---|---|
| `'x'` | letter `x` |
| `'2'` | numeric value 50 |
| `'\0'` | NULL char, value 0 |
| #define NEW_LINE '\012' | octal, 10 in decimal |
| #define NEW_LINE '\12' | '\ooo' 1 to 3 octal digits |
| #define SPACE '\x20' | hex, 32 in decimal |

16

## Character Constants: Example

```c
#include <stdio.h>

main() {
   char a, b, c, d, e, f;
   d = 'A';
   e = '\101';
   f = '\x41';
   a = 65;
   b = 0101;
   c = 0x41;
   printf( "%c %c %c %c %c %c\n", a, b, c, d, e, f)
}
```

17

## Escape Sequences

| | | | |
|---|---|---|---|
| \a | alert (bell) character | \\ | backslash |
| \b | backspace | \? | question mark |
| \f | formfeed | \' | single quote |
| \n | newline | \" | double quote |
| \r | carriage return | *ooo* | octal number |
| \t | horizontal tab | \x*hh* | hexadecimal number |
| \v | vertical tab | | |

18

## String Constants

```
"hello, world\n"

""  /* empty string */

\"  /* double quote character */
```

`"hello," " world"` same as `"hello, world"`

- concatenated at compile time
- useful for splitting up long strings across several source lines.

19

## Constant Expressions

- Expressions that involve only constants.
- Evaluated during compilation.

```
#define MAXLINE 1000
char line[MAXLINE+1];

#define LEAP 1 /* in leap years */
int days[31+28+LEAP+31+30+31+30+31+31+30+31+30+31];
```

20

## Enumeration Constants

```
enum boolean { NO, YES };
```

- The first name in an enum has value 0, the next 1, and so on, unless explicit values are specified.

```
enum colours { black, white, red, blue, green };
enum escapes { BELL = '\a', BACKSPACE = '\b', TAB =
  '\t', NEWLINE = '\n', VTAB = '\v', RETURN =
  '\r' };
```

- If not all values are specified, unspecified values continue the progression from the last specified value.

```
enum months { JAN = 1, FEB, MAR, APR, MAY, JUN, JUL,
  AUG, SEP, OCT, NOV, DEC };
  /* FEB = 2, MAR = 3, etc. */
```

21

## Limits

- File `limits.h` provides several constants
  - char `CHAR_BIT, CHAR_MIN, CHAR_MAX, SCHAR_MIN, …`
  - int `INT_MIN, INT_MAX, UINT_MAX`
  - long `LONG_MIN, …`
- You can find `FLOAT_MIN, DOUBLE_MIN, …` in `<float.h>`

22

## Declarations (2.4)

- All variables must be declared before use (certain declarations can be made implicitly by content).
- A variable may also be initialized in its declaration.

```
char esc = '\\';
int i = 0;
int limit = MAXLINE+1;
float eps = 1.0e-5;
```

23

## Qualifier `const`

- Indicates that the value of a variable will not be changed.
- For an array: the elements will not be altered.

```
const double e = 2.71828182845905;
const char msg[] = "warning: ";
```

- Used with array arguments, to indicate that the function does not change that array.

```
int strlen( const char[] );
```

- Note: The result is implementation-defined if an attempt is made to change a const.

24

# Arithmetic Operators (2.5)

**+ — * / %**

Examples:

```
abc = x + y * z;
j = a % i;
++x;
x++;
x += 5;    /* x = x + 5; */
y /= z;    /* y = y / z */
```

What is **x *= y + 1 ?**



# Precedence and Associativity

| Operators | Associativity |
|---|---|
| `() [] -> .` | left to right |
| `! ~ ++ -- + - * (type) sizeof` | right to left |
| `* / %` | left to right |
| `+ -` | left to right |
| `<< >>` | left to right |
| `< <= > >=` | left to right |
| `== !=` | left to right |
| `&` | left to right |
| `^` | left to right |
| `\|` | left to right |
| `&&` | left to right |
| `\|\|` | left to right |
| `?:` | right to left |
| `= += -= *= /= %= &= ^= \|= <<= >>=` | right to left |
| `,` | left to right |

## Type Conversion (2.7)

- `float f; int i;` What is the type of `f+i` ?
- General rule: convert a “narrower” operand into a “wider” one without losing information.
- So `i` is converted to float before the addition.
- `char` may be freely used in arithmetic expressions.

```
/* lower: convert c to lower case; ASCII only */
int lower( int c )
{
   if ( c >= 'A' && c <= 'Z' )
      return c - 'A' + 'a';
   else return c;
}
```

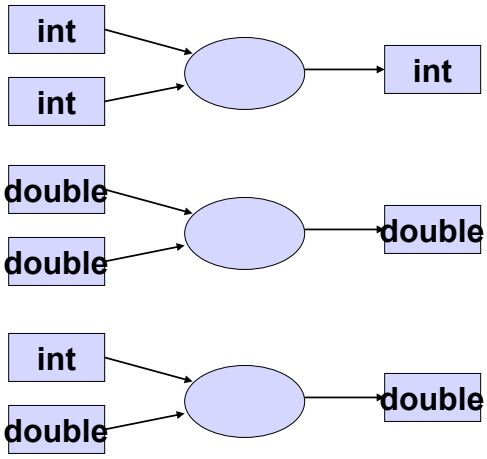
27

## Arithmetic Conversion

- When a binary operator has operands of different types, the “lower” type is *promoted* to the “higher” type before the operation proceeds.
- If either operand is long double, convert the other to long double.
- Otherwise, if either operand is double, convert the other to double.
- Otherwise, if either operand is float, convert the other to float.
- Otherwise, convert char and short to int.
- Then, if either operand is long, convert the other to long.

28

# Arithmetic Conversion: Examples




```
int a=5, b=2, c;
double x, y = 2;

x = a/b;
        // x = 2.0
c = a/b;
        // c = 2
x = a/y;
        // x = 2.5
c = a/y;
        // c = 2
```

29

# More Examples

- 17 / 5
  - 3
- 17.0 / 5
  - 3.4
- 9 / 2 / 3.0 / 4
  - 9 / 2 = 4
  - 4 / 3.0 = 1.333
  - 1.333 / 4 = 0.333

30

# Type Conversion: More Rules

- Conversions take place across assignments; the value of the right side is converted to the type of the left, which is the type of the result.
- Example:

```
int a;
float x = 7, y = 2;
a = x / y;
```

- `float` to `int` causes truncation of any fractional part.
- Example:

```
float x, y = 2.7;
int i = 5;
x = i;   /* x = 5.0 */
i = y;  /* i = 2 */
```

31

# Type Conversion: Even More Rules

- Longer integers are converted to shorter ones or to chars by dropping the excess high-order bits.

```
int i;
char c;
i = c;
c = i;
/* c unchanged */
```

```
int i;
char c;
c = i;
i = c;
/* i may be changed */
```

32

# Casting

```
int A = 9, B = 2;
double  x;
x = A / B;    /* x is 4.0 */
x = A / (double)B; /* C is 4.5 */

int n;
sqrt(double(n))
```

Doesn't change the value of B, just changes the type to double

- The cast operator has the same high precedence as other unary operators.

33

# Increment and Decrement Operators (2.8)

- ++ or --
- Placing in front: incrementing or decrementing occurs **BEFORE** value assigned

i = 2 and k = 1

k = ++i;

```
i = i + 1; 3
k = i;     3
```

k =--i;

```
i = i - 1; 1
k = i;     1
```

- Placing after: occurs **AFTER** value assigned

i = 2 and k = 1

k = i++;

```
k = i;     2
i = i + 1; 3
```

k = i--;

```
k = i;     2
i = i - 1; 1
```

34

# Precedence and Associativity

| Operators | Associativity |
|---|---|
| `() [] -> .` | left to right |
| `! ~ ++ -- + - * (type) sizeof` | right to left |
| `* / %` | left to right |
| `+ -` | left to right |
| `<< >>` | left to right |
| `< <= > >=` | left to right |
| `== !=` | left to right |
| `&` | left to right |
| `^` | left to right |
| `\|` | left to right |
| `&&` | left to right |
| `\|\|` | left to right |
| `?:` | right to left |
| `= += -= *= /= %= &= ^= \|= <<= >>=` | right to left |
| `,` | left to right |

35

# Examples

int a=2, b=3; c=5, d=7, e=11, f=3;

f += a/b/c; 3

d -= 7+c*--d/e; -3

d = 2*a%b+c+1; 7

a += b +=c += 1+2; 13

Note: Do NOT write code as above. Hard to read and debug!

36

## Relational and Logic Operators (2.6)

- Relational operators:
  `>  >=  <  <=`
  `==  !=`
- Logical operators:
  `!  &&  ||`
- Evaluation stops as soon as the truth or falsehood of the result is known.

```
for ( i=0;
   i < lim-1 &&
   (c=getchar()) != '\n' &&
   c != EOF;
   ++i )
     s[i] = c;

if (valid == 0)
/* same as */
if (!valid)
```

37

## Boolean Expressions

- False is 0; any thing else is true (1 and others).
- Write

```
if (!valid)
```

instead of

```
if (valid == 0)
```

38

## Assignment Operators / Expressions (2.10)

- A *= B; // equivalent to
- A = (A) * (B); // note the parentheses
- Can be used with: `+ – * / % << >> & ^ |`

```
yyval[yypv[p3+p4] + yypv[p1]] += 2

/* bitcount: count 1 bits in x */
int bitcount(unsigned x) {
   int b;
   for ( b = 0; x != 0; x >>= 1 )
        if ( x & 01 )
              b++;
   return b;
}
```

39

## Conditional Expressions (2.11)

**`exp1 ? exp2 : exp3`**

- If exp1 is true, the value of the conditional expression is exp2; otherwise, exp3.

```
z = (a > b)? a : b; /* z = max (a, b)*/
```

- If **`expr2`** and **`expr3`** are of different types, the type of the result is determined by the conversion rules discussed earlier.

```
int n; float f;
(n > 0) ? f : n
/* result of type float in either case */
```

40

## Conditional Expressions: Advantage

- Succinct code
- Example 1:

```
for (i = 0; i < n; i++)
  printf("%6d%c", a[i],
      (i%10==9 || i==n-1) ? '\n' : ' ');
```

- Example 2:

```
printf("You have %d item%s.\n", n,
  n==1 ? "" : "s");
```

41

## Bitwise Operators

42

# Bitwise Operators (2.9)

- Work on individual bits

  `&  |  ^  ~`

- Examples:

```
short int i=5, j=8;
k=i&j;
k=i|j;
k=~j;
```

```
a = 1;
b = 2;
c = a & b; /*c = 0*/
d = a && b; /*d = 1*/
```

- Application: bit masking

```
#define SET_ON 0XFFFF
int n, x;
n = n & 0177;
x = x | SET_ON;
```

43

# Bit Shifting

- x<<y means shift x to the left y times.
  - equivalent to multiplication by $2^y$
- x>>y means shift x to the right y bits.
  - equivalent to division by $2^y$
- Left shifting 3 many times:

**0 3**
**1 6**
**2 12**
**3 24**
**4 48**
**5 ...**

44

## Right Shifting

- It could be logical shift (filled with 0) or arithmetic shift (keep the sign of signed numbers)
- If unsigned numbers, then logical shift; if signed then undefined in C (implementation dependent)

```
unsigned int i = 714;
```
357 178 89 44 22 11 5 2 1 0

- What if `i = -714`?

-357 -178 -89 . . . -3 -2 -1 -1 -1 -1

(assume 2's compliment and arithmetic shift)

45

## Bitwise Operators: Examples

```
x = x & ~077;
```
sets the last six bits of x to zero.

```
/* getbits: get n bits from position p */
unsigned getbits(unsigned x, int p, int n)
{
  return (x >> (p+1-n)) & ~(~0 << n);
}
```

46

## Precedence and Order of Evaluation (2.12)

| Operators | Associativity |
|---|---|
| `() [] -> .` | left to right |
| `! ~ ++ -- + - *` (*type*) `sizeof` | right to left |
| `* / %` | left to right |
| `+ -` | left to right |
| `<< >>` | left to right |
| `< <= > >=` | left to right |
| `== !=` | left to right |
| `&` | left to right |
| `^` | left to right |
| `\|` | left to right |
| `&&` | left to right |
| `\|\|` | left to right |
| `?:` | right to left |
| `= += -= *= /= %= &= ^= \|= <<= >>=` | right to left |
| `,` | left to right |

47

## Next Lecture …

- Pointers (Chapter 5, C book)

48